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STEM ROT OF CLOVERS AND ALFALFA AS A CAUSE OF "CLOVER SICKNESS"

BY

A. H. GILBERT and D. S. MYER

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INTRODUCTION.

The fact that clovers and alfalfa are crops of the utmost importance both from the standpoint of forage production and as an aid in maintaining soil fertility, is bringing us to realize that the widespread failure to grow these crops successfully is a serious problem in the agriculture of Kentucky and other regions. The fact that in many cases repeated failures are being reported on lands which have produced clover successfully in the past adds seriousness to the problem. These failures at first were attributed to adverse climatic and soil conditions such as drought, winter killing or heaving, and soil acidity, and rightly so in some cases; yet there are other cases where the failure of the crop cannot be attributed to these conditions.

Land which has been producing good stands of clover and then without apparent cause ceases to grow clover successfully is called "clover sick." The term "clover sick" is a much abused term which is applied rather loosely to all conditions where repeated failures of clovers have been reported. A number of explanations as to the cause of "clover

sickness'' have been advanced. Some of the more important ones are as follows:

1. Soil exhaustion or the lack of one or more essential elements of plant food in an available form.
2. Soil acidity, or the lack of lime.
3. Injury caused by toxic substances excreted by the roots of plants.
4. Lack of inoculation, or inactivity of nodule organisms.
5. Destruction by insects.
6. Destruction by parasitic plants or fungi which live in the tissues of the plant.

Any of these suggested conditions might be the cause of failure, but in this publication the last one named (No. 6) is the one with which we are concerned.

There has appeared in Kentucky, and in several other states, a fungus disease, a ''stem rot'', (*Sclerotinia trifoliorum* Erik) of the clovers and alfalfa, which bids fair to become a very formidable enemy of these crops. Upon investigation of reported failures or partial failures of clovers and alfalfa during the winter and spring, this fungus disease has been found in many cases to be the cause of the failure. The disease has been under observation for the past several months and within that time many fields which were seriously damaged have been examined. Most of these fields were located in the Central Bluegrass Region of Kentucky on very fertile soils which had formerly produced good crops of clover. The disease has also been observed in other sections of the State and under different conditions as will be noted later.

This disease has been under observation in Kentucky for only a short time; however, it seems desirable at this time to publish a preliminary report in order to furnish information as to the importance, history, distribution and characteristics of the disease, together with the life history of the causal organism and to point out the methods of control which are known at present.

Historical.

The "stem rot" of clovers and alfalfa (previously referred to also as "clover sickness") has been known in Europe and England for more than fifty years and has there been the subject of considerable investigation. According to Eriksson, a German authority, the first recorded occurrence of the disease was in Germany in 1857, and the first case in which clover sickness was attributed to the fungus under consideration as the cause was reported by Hermann Hoffman in 1863.[1] In 1872 a paper containing a very full description of the disease and a life history of the causal organism, together with suggestions as to treatment, was published by Emil Rehm of Gottingen, Germany[2]. This paper pointed out that the disease was a very serious one in certain sections of the country, and that it was especially difficult to control on account of the settled custom of the farmers there to grow much alfalfa (lucerne) and clover, and on account of the practice of keeping fields in clover for a period of several years. This practice encouraged the disease to become better established and to spread. The only recommendation of the author was the rotation of crops so as to remove from the diseased fields the crops which served as hosts for the fungus. After several years during which the land had been in other forage crops, clover and alfalfa might again be grown with safety.

In England investigations of "clover sickness" by Lawes and Gilbert date back to 1849 and were continued through nearly thirty years, but it was not until about 1898, according to Gussow[3], that the cause of the disease was there definitely ascribed to a fungus. In addition to its occurrence in England and Germany, this disease has also been reported from Sweden[1], from Denmark[4], and from Canada*. In Canada, Gussow reports only one case of the disease but is very much concerned as to its spread.

Although in Europe the disease has been prevalent for many years, in this country it is of more recent occurrence,

[1]Refers to Bibliography.
*Information as to the occurrence in Canada was received by correspondence from H. T. Gussow, Botanist of the Dominion of Canada.

and has not as yet become so great a menace as it is abroad. Chester of Delaware[5], in 1890, seems to have been the first to report upon the disease in this country. He tells of its occurrence upon crimson clover and cites the earlier work of Rehm and others in Europe. The recent reports from various states and the observations made in Kentucky and on local fields suggest that the disease is here becoming more prevalent. Information as to its occurrence with greater or less seriousness has been received from New Jersey, New York,* Virginia, Indiana and Oregon, showing a wide distribution over the country. It is likely that it also occurs at other points, although it is reported as not occurring in West Virginia, Wyoming, Wisconsin, Nebraska, Minnesota, Connecticut and Louisana. In Clark County, Indiana,† a survey of eighteen alfalfa fields showed the disease present in all of them, in several cases the greater part of the stand being destroyed. In Oregon the disease is quite prevalent in the western part of the State, and it is now being investigated‡ in that state. From Virginia, Reed reports that it is doing considerable damage in certain localities but is not a widespread disease. Investigations are being undertaken at the Virginia Experiment Station.

Recent information as to its definite occurrence has been received from several counties in Kentucky. From the reports and observations during 1914-15, the disease has been found widely distributed throughout the State. It has been reported from Simpson and Logan counties in the southwestern part of the State, also from Boone County in the north. Oldham, Franklin, Lincoln, Woodford, Fayette and Jessamine are other counties in which the disease has been observed and has done serious damage. For the most part these counties have fertile soils.

In several fields of the Kentucky Agricultural Experiment Station farm, the disease has been under observation for more

*F. C. Stewart reported observing a disease upon alfalfa at Phelps, N. Y. (1901), which was probably the disease under discussion.
†Information from G. N. Hoffer, of Purdue University.
‡Report by H. S. Jackson, Corvallis, Oregon.

than a year, and during the spring of 1915 was reported and observed in a number of fields in Central Kentucky.

Description of Disease and Host Plants.

The disease has been given various names by authorities. In Europe it has been designated as "clover rot" or "clover cancer." It has also been called "wilt", "root rot" and "stem rot". These terms all apply to the same disease. In this publication it will be designated as a "stem rot" of clovers and alfalfa.

The disease has been observed in Kentucky in fields of
Alfalfa (*Medicago sativa*),
Red Clover (*Trifolium pratense*),
Mammoth or Sapling clover (*Trifolium pratense perenne*),
White clover (*Trifolium repens*),
Crimson clover (*Trifolium incarnatum*).

It has not been observed on alsike clover (*Trifolium hybridum*) here as yet but according to Rehm and Kuhn the disease attacks this species. It has not yet been reported on sweet clover and other minor legumes. On one occasion it was found forming sclerotia on spotted spurge (*Euphorbia maculato L.*) a common weed.

The disease was first observed on the Experiment Station farm in January, 1914, in a field of young alfalfa which had been seeded the preceding fall. Dead plants were noticed and the cause was found to be a rotting or decaying of the plant at the crown, or just below the crown. Further observation revealed the presence of the disease in another field on the Experiment Station farm which was seeded at the same time as the one just mentioned. By May 1st at least 50 per cent of the plants were killed out in these two fields. One of the fields was plowed during June, 1914, limed heavily and reseeded to alfalfa in August. A few of the plants were killed out during the following winter and spring but the damage was very slight. This was partly accounted for by the fact that the spring was very dry. Further, the fact that the sclerotia or bodies which serve to reproduce the

fungus were plowed under and only those near the surface were able to germinate, probably helped to control the disease.

The effects of the disease may appear in the fall, winter or spring. It does its damage during the period from October to June and seems to be most active in this region during the months of October, November, February, March and April, yet it is found to some extent earlier in the fall and later in the spring, and, when weather conditions permit, may become very active during December and January.

When the very succulent or growing plant is attacked by the disease, the leaves turn brown and the plant wilts down. When the plant is more or less dormant, it may wilt down and die retaining the green color in the leaves for some time. The stem finally turns yellowish or brown and rots off at a point near the crown. Oftentimes a whitish, mold-like fungus growth is found on the leaves and stems of the plant. For the most part this white fungus growth appears at the base of the plant, sometimes above and sometimes just below the crown, causing a decay of the tissues and the subsequent death of the plant. In some cases we find only a few stems of the plant injured while the others remain healthy; especially is this true of old, vigorous or well established plants. The main distinguishing character of the disease is the formation, in the spring, of sclerotia, which are produced from the mycelium that penetrates the tissues of the plant. At first these sclerotia are white in color but gradually become more dense and turn to a bluish or black color. They are generally found just below the surface of the ground attached to the stem, or borne within the tissues of the stem in many cases, although at times formed above ground on the stem of the plant; especially is this true of white clover (*Trifolium repens*) which has creeping stems. Plants which are suspected of having the disease should be lifted out of the ground by cutting off the root an inch or two below the surface, taken up carefully and the stems examined near the crown for the fungus growth or the sclerotia just described. The sclerotia are not found as a

general rule until the disease has about run its course and for this reason they are more often found on plants completely dead than on plants that are just beginning to wilt.

In many cases the disease appears in localized areas in the field causing the plants to die out and giving the field a more or less spotted appearance, while in other cases it may be found in all portions of the field and thins out the stand rather regularly or destroys it almost completely. If the bare spots are examined in the spring, dead and decaying plants will likely be found bearing the black sclerotia which serve to carry the disease over in the soil until the next year.

The disease seems to do more injury in young fields than in old or well established ones. All the cases reported or observed have been in young fields sown the preceding spring or fall. The disease has been observed in two year old fields of alfalfa but the damage was much less than on the younger stands. Undoubtedly the older well established plants are better able to resist the attacks of the disease. If for any reason the vitality of the plant is lowered as by drought or insect attacks for example, the plant thereby seems to become much more susceptible.

The means by which this disease gains access into a new region is a matter of speculation. It has been suggested that it is distributed by means of the seed, but since, so far as we know, no experiments have been carried out which support this theory, we cannot be sure that this is the case. In infected fields the sclerotia may be distributed or spread about by cultivating implements, such as plows, harrows, etc. These sclerotia may be carried from one field to another or from one farm to another in soil used for inoculation of legumes. There is also a possibility that some of the smaller sclerotia may become mixed with the seed at hulling time, especially in cases where the seed is trampled out by animals, as is the case with much of our imported Turkestan alfalfa seed and some other imported seeds. This manner of hulling increases the chance for mixing the sclerotia with the seed.

Life History of the Causal Organism.

The fungus which causes the particular "stem rot" under discussion belongs to the Ascomycetes, and is listed in recent textbooks under the name *Sclerotinia trifoliorum* Erik* Its life history has been fully investigated and may be briefly outlined as follows:

During the winter and early spring the fungus exists in its vegetative condition, first as a saprophyte in the soil and then as a parasite upon the host plant. In this vegetative form it is a delicate, thread-like, branching structure, which, upon coming in contact with the young alfalfa or clover plant, penetrates it and develops an extensive growth within the tissues, occupying the cells and eventually causing their complete decay. The point of first infection is just below the surface of the soil where the hyphae can develop under favorable moisture conditions. The complete decay of the host plant is due to the parasite and to later attacks of other organisms which at length result in the entire disintegration of the plant.

The spores which give rise to the vegetative stage in the soil, come from the fruiting bodies of the previous season. Under suitable conditions during the months November to January these spores germinate, forming among the loose surface soil particles a delicate, filamentous, branching mycelial growth. For a few days, or longer, if the conditions are favorable, the fungus continues its growth, sending out its mycelial threads among the soil particles until these threads come in contact with a young alfalfa or clover plant when infection takes place as indicated above. It has not been shown how long the fungus can exist in the vegetative condition in the soil before coming in contact with a host plant, but the length of time is probably dependent upon moisture and temperature conditions and also upon the physical texture of the soil.

*According to Eriksson[1] the fungus was first described by Fries and Rabenhorst under the name *Peziza ciborioides* Fries. This name was discarded by Eriksson who assigned the name *Sclerotinia trifoliorum* Erik (1880). Still a third name, *S. ciborioides* Rehm is given by Gussow[3] as most tenable. We will not in this article attempt to settle the question of nomenclature, but are temporarily adopting the name *Sclerotinia trifoliorum* Erik. A further discussion as to the priority of names will appear in a later paper by one of the present writers.

The vegetative phase of the fungus seems to prevail more or less from October or November to February or March. Toward the end of this vegetative phase the fungus threads in the stems and roots become massed together and form in the center and on the surface of the plants near the crowns roundish or irregular shaped sclerotia, varying in size, some as small as a mustard seed, others as large as a pea. At first the sclerotial bodies are white but later they become black, and upon the decay of the plants remain in the soil and serve as resting bodies to carry the fungus over to the next season. (Plate I. Fig. 2 and Plate II). In the fall these sclerotia germinate, sending up slender stalks from one-fourth to three-fourths of an inch in length, at the ends of which are the disk-like apothecia one-fourth to one-half of an inch in diameter. (Plate II). From these disks spores are discharged which germinate and again form the vegetative phase of the organism, thus completing the life history.

It is not known exactly under what conditions the spores are discharged but apparently this occurs at different periods from October to February. An abundance of the fruiting bodies were found in the field of Prof. A. M. Miller, of Lexington, Kentucky, on November 13, 1914, and in the same field fruiting bodies were found in December and January, showing that they are developed from the sclerotia at intervals during the fall and early winter. The depth of soil under which the sclerotia lie, and the texture of the soil determine to a considerable extent the time of appearance of the fruiting bodies.

Suggested Methods of Control.

There has been no accurate experimental work successfully carried out to determine methods of control or treatment of this disease, mainly because "clover sickness" has in the past been very generally attributed to soil conditions or some other cause. Experimental work with fertilizers and manures has been carried out on "clover sick" land by Rehm and also at the Rothamsted Station without success.

FIGURE I.

FIGURE II.

Plate I. Fig. I. Young plants (8 months old) of alfalfa showing the "stem rot." (a) Enlargement and discoloration just below the crown. Fig. II. Plant of alfalfa whose roots are completely rotted away and which shows sclerotia (b) formed just below the crown.

The following quotation from Lawes and Gilbert[10] sums up the work: "When land is what is called 'clover sick' none of the ordinary manures whether artificial or natural can be relied upon to secure a crop."

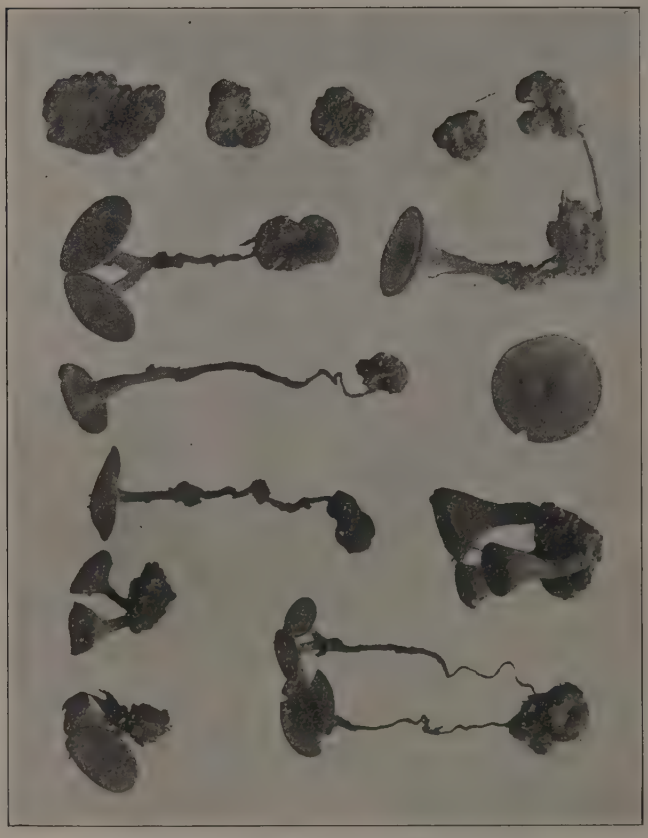

PLATE II.
Plate II. At the right a row of Sclerotia showing their characteristic rough surfaces and lobed form. At the left Sclerotia which developed stalks and spore producing bodies (apothecia).

The most logical method of control at present is the use of a rotation leaving out the clovers or other host plants for a period of years on badly infested fields. In Germany and some other countries where the clover crop has become

unprofitable on account of "clover sickness," farmers have had to resort to this means of control. It is not known how long the disease will remain in the soil, but if none of the host plants are grown in a field over a period of four to six years it is probable that the disease would do little damage at the end of that period. In the absence of host plants, De Bary[7] has shown that the disease may live as a saphrophyte, that is, live on dead organic matter in the soil. Frank[15] has shown that the sclerotia may lie over in a dry condition and still germinate after two and one half years. It is not known how much longer they will remain viable.

In case clovers are to be left out of the rotation, other leguminous crops which are not susceptible should be substituted, such as soy beans or cowpeas. These two crops are summer annuals and make their growth when the disease is in the dormant stage. So far as is known, these crops are not attacked by the disease. It has never been reported on the vetches, or sweet clover. However, it is not definitely known that these crops are free from attacks of the disease.

Deep plowing is another means of control that has been suggested by Rehm. If the badly infested field is plowed deeply some time during the summer, most of the sclerotia will be covered so deeply that the fruiting bodies will be unable to reach the surface. Even if some of them are able to germinate and scatter spores, the damage will in most cases be greatly lessened. This practice was successful in a field on the Kentucky Agricultural Experiment Station farm, as already noted.

Treatment of the seed naturally suggests itself as a control measure, but since we are not sure that the disease is carried on the seed, and have not carried out any experiments with seed treatment, it cannot be set forth as a control measure. It can only be suggested as a possibility. It is possible that selection of disease resistant strains would be an important means of combating the disease, but this also remains to be investigated.

Since healthy and well established plants seem to be much

more resistant, good cultural methods naturally should enter in as a control measure, though we have mentioned the fact that the disease is found in the most fertile soils. Good drainage, good physical condition of the soil, plenty of organic matter, lime, a well prepared seed bed and favorable seeding time, are all necessary in producing leguminous plants of strong vitality. On a soil with these requirements, the plants become established more quickly and are generally more resistant to disease.

Summary.

1. Repeated failures of clover and alfalfa have been ascribed to "clover sickness". Many explanations have been advanced as to the cause. In this publication "clover sickness" or "stem rot" as caused by the parasitic fungus (*Sclerotinia trifoliorum* Erik) is discussed. It was recorded in Germany as early as 1857. It has been observed and studied in England, Canada, Denmark and Sweden. At present it is becoming increasingly prevalent in certain regions of the United States. It has been observed in Kentucky during the years 1914-15, and has been found to be quite widely distributed throughout the State. In some sections it has been found doing serious damage.

2. The disease occurs in Kentucky on alfalfa, red clover, mammoth clover, white clover, and crimson clover. It has been reported on alsike clover by foreign authorities. The damage due to the disease occurs largely during the months from October to May. The disease causes a wilting of the plants and a decay of the tissues at the point of infection, which is just below or at the surface of the ground. The affected plants may occur in localized areas, resulting in the killing out of the plants in spots, or it may be distributed very generally over the field, thinning out or completely destroying the stand. Black sclerotia are formed on the stems at or below the crown and serve as a means of carrying over the disease.

3. The fungus exists during its vegetative stage as a mycelial growth in the soil and within the tissues of the plant. This stage is followed by a production of sclerotia upon and within the tissues. The sclerotia, after several months, may germinate forming disk shaped spore producing bodies (*apothecia*). Spores from this fruiting stage upon germinating in the fall develop again the vegetative stage of the organism. Spore germination takes place in the moist soil but soon the fungus becomes parasitic and causes the death of the host plant.

4. There has been no experimental work carried out which has proved of definite value in controlling this disease. The methods of control which have been suggested up to the present are as follows: First, a rotation of crops should be practised which leaves the host plants out of the rotation for a period of years, whenever the disease becomes serious. Second, deep plowing in summer during the dormant period of the disease will serve as a method of control, by covering the sclerotia to a depth which will prevent their germination. Third, proper methods of soil preparation and seeding should be followed so as to give the plants a vigorous start. When the disease becomes very serious, soy beans, cowpeas or other summer annual legumes may be substituted for the clovers in order to keep a leguminous crop in the rotation.

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